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# POLARITY

## FROM DIPOLES TO BIOPOLARIZATIONS

## III. ADDENDA

by

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"La Polarité'' was first proposed in 1765 in the Encyclopédie by Diderot and d'Alembert to designate''la propriété qu'a l'aimant ou une aiguille aimantée de se diriger vers les pôles du monde'', one century before its first use in Biology by Allman (1864, see **I**).

The whole field of natural Polarity therefore covers the wide span recently surveyed (Turian, 1989-1990, **I** and **II**, updated in these **III**) from its physico-chemical fundaments to the multiple aspects of biopolarity. In this evolutionary perspective, Polarity was considered as the dual, directional principle of ''space-time arrow'' of Nature which, after having broken the original, neutral symmetry into the asymmetric couple of oppositely charged (+/-) subatomic electric particles of primeval matter, led through molecular and then macromolecular dipoles to the morphogenetic gradients of polarized and hierarchized biopatterns. As such, Polarity might thus be the answer to the old quest of the unifying principle behind the bewildering diversity of Nature, intuitively suggested by the Yin-Yang of oriental philosophies and rationally searched by the philosophers of ancient Greece.

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The electromagnetic forces involve the underlying attractions and repulsions of positively charged atomic nuclei and their surrounding negatively charged electrons. Their disturbance liberates radiation which emerges as quantum bundles of electrically neutral and massless photons. If there were electrically charged, positive and negatively charged photons, these could attract and form neutral clusters of light or ''photon-balls''. However, there is a still ambiguous possibility that ''there should exist new forms of matter such as ''glueballs'' which are similar in spirit to these imaginary photon-balls'' (Close, 1991).

Another couple of opposite electric charges is that of the positively charged proton and the negatively charged antiproton. Now, much is expected for further understanding of elementary particles from the smashing protons-antiprotons after their acceleration in the powerful particle accelerator Tevatron (Lederman, 1991).

Radioactive nuclear decay processes have many chemical consequences. The primary cause of the ensued ionization is the change of chemical identity, hence of the nuclear charge, undergone by the radioactive atom. Such a ''transmutation'' effect leads to the formation of monovalent cations by $\beta^-$ decay and monovalent anions by $\beta^+$ decay or by electron-capture processes (Cacace, 1990).

2) *Electric dipoles*

The theory of electric polarization has been reviewed by Böttcher *et al.* from 1973 to 1978, and more recently by Blaive (1980). For this theory, the electric moment of a system of charges is a fundamental notion. According to Coulomb's law, the force between two point charges +e and -e evolves according to inverse square law. Generally, the polarization depends on the electric field strength. For example, surface charge density on a conducting sphere in a uniform field is axially asymmetric and this charge distribution can be solved by Laplace's equation (see Böttcher *et al.*, pp. 30-33, 1973). In Maxwell's electrostatic theory, matter is treated as a continuum and the vector fields are of importance to ascribe a dipole density to matter.

Electric dipole, quadrupole, and magnetic transition probabilities of ions isoelectronic to the first-row atoms have been reviewed by Cheng *et al.* (1979) and NMR spectra quadrupolar nuclei interpreted by Engstroem (1980). In aqueous solutions and biological systems, quadrupolar ions have been studied by NMR (Reimarsson, 1979) and chemical and biological agents detected by triple quadrupole mass spectrometry (Bauer, 1987). For nuclear quadrupole resonance spectroscopy, see Brown *et al.* (1983).

Giant electric and magnetic multipole resonances have been microscopically described by Sanchez-Dehesa (1977). Excitation of giant multipole resonances through inelastic scattering has been reviewed by Bertrand in 1976 and 1980 and giant multipole resonance experimentally recently studied in nuclei by Hakansson (1988).

Polarization asymmetries predicted by quantum chromodynamics, the ''grand unification'' of all particle forces, have been surveyed by Baldracchini *et al.* (1981).

Particles in QCD are known to be asymptotically free, that is at high energies quarks and gluons are weakly coupled, while at low energies they appear to be confined in hadrons - the nucleons protons and neutrons - and mesons (Olive, 1991).

3) *Polarized conductivity*

Unipolar high-frequency discharges and electronic processes in unipolar solid-state devices have been studied respectively by Trunecek (1965-67) and Dascalu (1977). Polarization and ''decomposition'' of copper and silver have been studied by Lehmann in 1975.

With the years, rectifier tubes have been replaced by barrier diodes and then the three-terminal transistor replaced the vacuum triode used for signal modulation or amplification. Physics of polarons and excitons in polar semiconductors and ionic cristals have been reviewed by Devreese and Peeters (1982). Field-effect and bipolar power transistor physics have been reviewed by Blicher (1981) and the bipolar junction transistor recently discussed by Neudeck (1989). For design and realization of bipolar transistors, see Ashburn (1988). A bipolar-compatible monolithic capacitive pressure sensor has been presented by Sandar (1980) and bipolar and MOS analog integrated circuit design has been studied by Grebene (1984). The fast advancing field of solid-state electronics which includes first the replacement of discrete circuit elements and the integration of many circuit elements onto hybrid ferromagnetic metal-semiconductors (iron/gallium arsenide as well as iron/zinc selenie) chips were recently surveyed by Prinz (1990).

According to the theory of Bardeen-Cooper-Schrieffer (BCS), low temperature superconductivity is a process in which conducting electrons somehow become ''pair-bonded'' into packets that slide through the superconductor's atomic lattice at low temperatures without the resistance encountered by single electrons. The reality of electron pairs has found support in magnetic flux measurements demonstrating that quantized units of flux - known as ''fluxons'' - ''are inversely proportional to twice the electronic charge in high-temperature superconductors'' (Hamilton, 1990).

Among the difficulties faced by this $T_c$ superconductivity or BCS theory is that of a partial disorder that defies the classical periodic symmetry of solid-state physics. However, the theory is unaffected by scattering that breaks long-range translational order. Such symmetry breaking effects are ''in no way of essence to the fundamentals of the theory, so long as the relevant order parameter is nonzero in all directions'' (Schrieffer, 1991).

## D. Magnetic polarization

1) *Cosmological level*

Related to the ''sun spot cycle'' (see Foukal, 1990, in **II**), sun spot pairs have been described as huge magnetic dipoles displaying an opposite orientation in the Northern Hemisphere to that in the Southern Hemisphere (Foukal, 1990).

Stellar genesis implicates powerful bipolar molecular outflows which remove circumstellar cloudy materials (Lada and Shu (1990).

Two of the most common cosmic defects with superstrings are the evolution of monopoles (see I.D.3) and texture. Nematic liquid crystals thought to be a fluid made of rodlike molecules have provided a model for their theoretical study on time and space scales at laboratory levels. Dynamical instability of texture has thus been unraveled by its decay into a monopole-antimonopole pair (Chuang *et al.*, 1991).

2) *Magnetic fields*

According to the so-called Ubbelohde effect (Robertson and Ubbelohde, 1939) the substitution of deuterium for hydrogen in hydrogen-bonded materials can lead to a change in the geometry of the hydrogen bonds. Using the new neutron diffraction technique, McMahon *et al.* (1990) demonstrate the effect of that substitution in $KH_2PO_4$. This prototypical hydrogen-bonded ferroelectric spontaneously acquires an electric dipole below a critical temperature. Two coupled subsystems, the proton tunnelling subunit, and the host lattice molecule have been considered in the determination of the process of proton ordering, and the development of polarization upon transition from the disordered to the ordered, ferroelectric state. Such proton-tunnelling units are embedded in molecular compounds such as ice (see II.B.1. in **I**) and biomolecules such as rhodopsin (see IV.B.b. in **I**) which thus examplify cooperative proton-tunnelling.

High-resolution solid-state NMR techniques were originally developed to enhance resolution by attenuation of dipolar couplings and other anisotropic interactions. Rotationally resonant magnetization exchange, a new nuclear NMR technique, has been applied by Creuzet *et al.* (1991) to the determination of the structure of membranar bacteriorhodopsin.

Magnetic fields have been modelled on a sphere with dipoles and quadrupoles by Knapp (1980) and magnetic dipole transitions studied in atomic and particle physics by Sucher (1978). There is a parallel, predicted by general relativity, between gravity and electromagnetism. According to this so-called gravitomagnetic effect, every electric charge has an electric field. A moving charge also generates a magnetic field, which influences other moving charges. As for the positively charged atomic nucleus, it is in motion, creating a magnetic field (see Appenzeller, 1990).

3) *Magnetic monopoles*

Following Monopole '83 (Stone, 1984) and a study of magnetic monopoles by Giacomelli (1984), the geometry and dynamics of magnetic monopoles have been reviewed by Atiyah and Hitchin (1988) and Horvathy (1988).

Magnetic monopoles are thought to be solitary poles, labeled north or south; unlike the two varieties of electric charge, positive and negative, which are often observed in isolation, magnetic poles seem to occur only in pairs ... ''Nature, it seems, abhors a

monopole'' ! (von Baeyer, 1990). However, Cabrera had obtained a positive result in 1982 which, unfortunately he has recently discarded (Cabrera, 1990).

Magnetic monopoles have been a long-standing problem for grand unified theories. Symmetry-breaking leads to the appearance of global monopoles which occur in abondance in liquid crystals (see I.D.l). The structure of monopoles and their apparent cylindrical but not spherical symmetry is now discussed in terms of the minimal energy solution which is cylindrically rather than spherically symmetric (Chuang *et al.*, 1991).

4) *Spin polarizations*

It is in 1945 that Purcell, Pound and Torrey detected the nuclear magnetic resonance (NMR) response of protons in paraffin and that Bloch, Hansen and Packard registered that of protons in water. Since then, advances in NMR spectroscopy have revolutionized chemical and biochemical analysis followed by medical diagnostics. Nuclear dipolar magnetic ordering, and heteronuclear dipolar couplings, total spin coherence, and bilinear rotation have been reviewed by Goldman (1977) and Garbow (1983) repectively.

Principles of dynamic nuclear polarization, chemically induced (Kaptein, 1975), have been reviewed by Abragam and Goldman (1978) and those of correlation and polarization reviewed by Crowe and Rudge (1988). Dynamic nuclear polarization in liquids and solids and nuclear pseudomagnetism in making polarized targets for high-energy experiments are among Abragam's (1989) most notable achievements.

## E. Light polarization

Polarization is relevant for optical systems (Chipman, 1988, 1990) and induced polarization had been reviewed by Dodds (1976).